

TOPOGRAPHIC AND GEOLOGIC

ATLAS

of

PENNSYLVANIA

A 127

LOYSVILLE

QUADRANGLE

JOHN T. MILLER



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A 127

GEOLOGY AND MINERAL RESOURCES
of the
LOYSVILLE QUADRANGLE
PENNSYLVANIA

By
John T. Miller

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**GEOLOGY AND MINERAL RESOURCES
OF THE
LOYSVILLE QUADRANGLE**

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ABSTRACT

This report is a brief preliminary report accompanying the geologic map of the Loysville 15-minute quadrangle, at a scale of 1/24,000.

The Loysville quadrangle lies in the southern part of the Ridge and Valley Section of the Folded Appalachians in central Pennsylvania and stratigraphically and structurally is characteristic of this province.

The units mapped are all rock units and extend from the Martinsburg Formation at the base to the Catskill Formation at the top. The age of the rock units is from Upper Ordovician to Upper Devonian. One new member and two new formations are named and mapped in this report. They are: the Silurian Cabin Hill Member of the Rose Hill Formation, the Silurian Mifflintown Formation, a redefined rock unit composed of the Keefer, Rochester, and McKenzie units, now reduced to member rank for this area, and the Devonian Sherman Ridge Formation at the top of the Hamilton Group.

The folds of the Loysville quadrangle combine similar and parallel fold characteristics. Competent units form parallel folds and incompetent units form similar folds resulting in disharmonic relationships. Faults are primarily associated with competent units and are mostly high angle reverse faults. Overturning to the northwest is not regional; many axial planes of folds dip northwest as do some faults.

Exploitation of mineral resources is essentially nil, with few possibilities for future expansion.

INTRODUCTION

This report is part of a geologic mapping program being conducted in central Pennsylvania by the Pennsylvania Geologic Survey and is presented as a brief account of the geology. A later, more extensive report will include the geology of several 15-minute quadrangles and will present more fully the regional perspective of the stratigraphy and structure.

LOCATION

The Loysville quadrangle is located in south-central Pennsylvania and represents an area 13 1/2 miles east-west by 17 1/2 miles north-south. It occupies most of central Perry County and includes on the north and south small portions of Juniata and Cumberland counties respectively.

QUADRANGLE SUBDIVISION

The Loysville 15-minute quadrangle consists of four 7 1/2-minute quadrangles named Spruce Hill, Ickesburg, Andersonburg, and Landisburg (Index, Plate 1). In the text, for convenience in section locations, a 36 quadrangle scheme is used, with each 7 1/2-minute quadrangle subdivided into 9 subquadrangles (Figure 1). Thus the location symbol II-6 will mean subquadrangle 6 in the Northeast 7 1/2-minute, or Ickesburg quadrangle.

I-SPRUCE HILL			II-ICKESBURG		
1	2	3	1	2	3
4	5	6	4	5	6
7	8	9	7	8	9
III-ANDERSONBURG			IV-LANDISBURG		
1	2	3	1	2	3
4	5	6	4	5	6
7	8	9	7	8	9

Figure 1. Subquadrangle designations of the 7 1/2' quadrangles within the Loysville 15' quadrangle.

PREVIOUS WORK

The geology of the Loysville area was first investigated in the early 1800's on a state wide reconnaissance basis by the First Pennsylvania Geologic Survey, directed by H. D. Rogers (1858). The area was mapped in greater detail, at a scale of 1:125,000, by members of the Second Pennsylvania Geologic Survey, first by Dewees (1878) and later by Claypole (1885) in Perry County, and by Dewees (1878) and D'Invilliers (1891) in Juniata County. Most of the Second Survey work was of high caliber although it was hampered by poor topographic control with only county road maps as base maps.

No major works have been published for the Loysville area since the Second Survey reports. Brief stratigraphic reports and other papers cited throughout the text) have presented sporadic data for the Loysville area, but the details of the geology have needed revision for a long time, as is the case for a major portion of Pennsylvania.

ACKNOWLEDGMENTS

Credit for assistance and discussion is due to James Dyson of Lafayette College and to John Rodgers of Yale University for critical review of field work. The text was edited and completed by R. R. Conlin with the assistance of other members of the Pennsylvania Geological Survey.

PHYSIOGRAPHY

In Pennsylvania the Appalachian Mountains are subdivided into several major, north to northeast trending, physiographic provinces (Figure 2). The southeastern provinces comprise the complex metamorphic and igneous sequences of the Blue Ridge Province, the Reading Prong of the New England Province, and the Piedmont Province which includes the Triassic Lowland Section. Next west is the Appalachian Valley Province comprising two longitudinal subprovinces or sections, the Great Valley Section on the east, underlain by intensely deformed Cambro-Ordovician sedimentary rocks, and the Ridge and Valley Section on the west, underlain by less deformed rocks of Cambrian through Pennsylvanian age.

The topography of the Loysville quadrangle is typical of the Appalachian Ridge and Valley Section. The local relief is more than 1,600 feet, varying between the extremes of 480 feet along Shermans Creek and 2,118 feet along Tuscarora Mountain.

The ridges of the area can be subdivided into four orders of magnitude. The highest ridges are underlain by anticlines and homoclines

LOYSVILLE QUADRANGLE

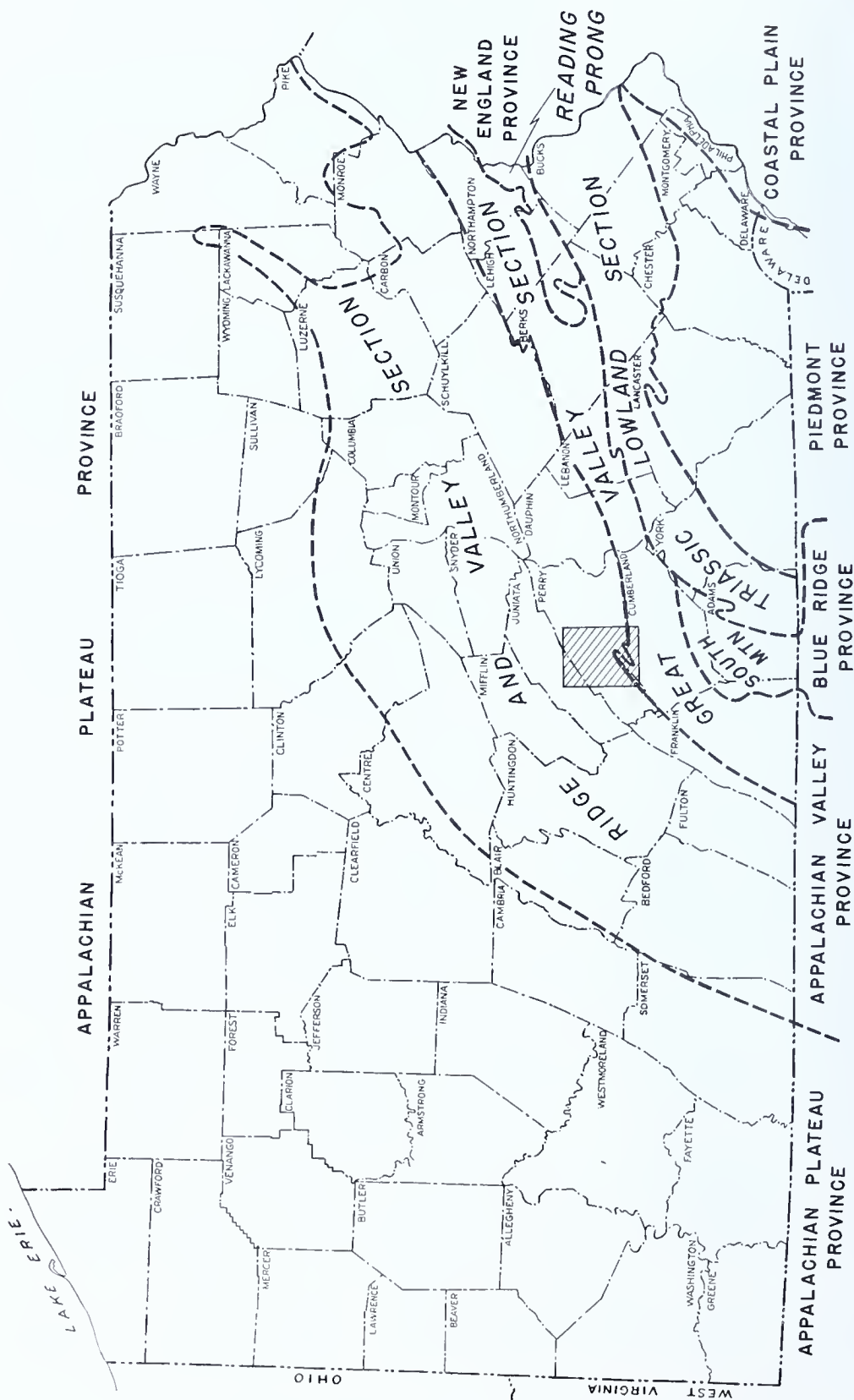


Figure 2. Physiographic subdivisions of Pennsylvania

n Lower Silurian sandstones and quartzites and attain a maximum elevation of 2,118 feet. The second highest ridges are underlain by thick Middle Devonian sandstones and shales which attain a maximum elevation of 1,269 feet. Ridges of similar magnitude parallel the flanks of the 1st order ridges and are underlain by Lower Silurian siltstones, shales, and sandstones. The third highest ridges, up to 981 feet elevation, are underlain by thick Upper Devonian siltstones and shales enclosed in an amphitheatre by ridges of the second order in the north-east portion of the quadrangle. Ridges of similar elevation parallel the flanks of the 2nd order ridges and are underlain by Lower Devonian sandstones and limestones.

The belt of lowlands which lies between the ridges of 1st and 2nd order comprise most of the ridges of 4th order magnitude which attain elevations of 650 to 800 feet. These ridges are underlain by Middle Silurian siltstones, shales, and argillaceous limestones.

The Loysville quadrangle is 60% mountainous and hilly woodland and 40% cultivated land. The major portion of the farmland is localized in the valleys underlain by Silurian limestones and calcareous shales. Previously, more of the area was cultivated but some soil types and the steeper slopes have gradually been converted to tree farming and pasture land, while some areas were abandoned altogether.

STRATIGRAPHY

The rocks exposed in the Loysville quadrangle range from Upper Ordovician to Upper Devonian in age. Minor Quaternary alluvium is present but has not been mapped. The Upper Ordovician rocks are exposed along the southern boundary of the quadrangle and in the cores of the Bowers Mountain and Tuscarora Mountain anticlines.

The Silurian Tuscarora Formation underlies the most prominent ridges along the southern boundary of the quadrangle and Bowers, Tuscarora, and Conococheague mountains. The remainder of the Silurian units underlie the down-dip slopes of these ridges and also the major valleys. Devonian rocks support the second order hills in the north-eastern and southeastern sections and also underlie some of the smaller valleys.

ORDOVICIAN SYSTEM

MARTINSBURG FORMATION

The Martinsburg Formation was named by Geiger and Keith (1891, p. 161) at Martinsburg, West Virginia. The name has been applied extensively throughout the Great Valley.

The Martinsburg Formation is exposed along the southern boundary of the Loysville quadrangle, south of Blue Mountain. The thickness of the formation is indeterminant in the area mapped owing to both incomplete exposure and structural complexity which, to be deciphered, must await extensive work in the Great Valley. Stose (1953) indicated a thickness of 2,000 feet in the immediate area and Willard (1943, p. 1082) suggested a 2,500 to 3,000 feet thickness a few miles to the east. An arbitrary thickness of 3,000 feet is used on the cross sections (Plate 2) of this report.

The Martinsburg Formation is a sequence of medium- and dark-gray to olive-gray shales with interbedded, subordinate beds of siltstone and light- to moderate-olive-gray, fine-grained sandstone. The upper 200 to 300 feet of the formation are characterized by dominant siltstone and fine-grained sandstone; the sand apparently increasing toward the top. In many places the siltstones show laminae and cross beds from two to six inches long. Some outcrops of shale and siltstone weather variegated, are laminated, and contain thin lenses of light-gray clay and fine-grained sand.

Two fossil localities were found in the Martinsburg Formation, both along the road south from Doubling Gap on the Andersonburg quadrangle. One locality occurs 20 to 30 feet stratigraphically below the base of the Juniata Formation. The faunal assemblage found here is similar to that found at other, nearby localities by Willard who assigned them an Eden age (Willard, 1943, p. 1092-1094). The other locality is along the same road 1.3 miles from the southern boundary of the quadrangle. Here the rocks yielded sheared graptolites (?*Climacograptus* sp.). The stratigraphic position of these graptolites within the Martinsburg was not determined.

The lower contact of the Martinsburg Formation is outside the limits of the Loysville quadrangle. The upper contact is not exposed, but where it crosses the road at Doubling Gap, the sandy beds and fossiliferous shale of the upper Martinsburg are exposed 30 to 50 feet stratigraphically below and apparently conformable to the lowermost beds of the Juniata Formation.

JUNIATA FORMATION

The Juniata Formation was named by Darton and Taff (1896, p. 2) but no type locality was given in their report. Clark (1897, p. 180-181) mentioned that the unit was named from typical exposures along the Juniata River of central Pennsylvania. The name Juniata has been applied extensively to a dominantly red-bed sequence in the Ridge and Valley Section of Pennsylvania.

The Juniata Formation crops out on the escarpment slope below the monoclinical ridge crests held up by the Silurian sandstones. The sandstones of the upper Juniata Formation occur at the ridge crests and in breached valleys of the Tuscarora and Bowers Mountain anticlines. Eight hundred feet of the Juniata Formation is exposed at Run Gap in Tuscarora Mountain but the total thickness is in excess of this figure. Interpolation between sections along Blue Mountain and known thicknesses in the Mifflintown quadrangle indicate a thickness of 1,000 to 1,200 feet at Run Gap. This thickness is in distinct contrast to the 40 feet exposed at the Susquehanna Gap 20 miles to the east. Swartz (1955, p. S-10) gives a summary account of the subdivisions of the Juniata Formation which he has identified over a period of years. He subdivides the formation into three members, the upper or Run Gap Red Sandstone Member, the middle Plummer Hollow Mudstone Member, and the lower East Waterford Red Sandstone Member. The quartzitic lithology of the Run Gap Member is easily distinguishable from the rest of the formation where outcrop is extensive, but talus cover on the slopes of the ridges prevented mapping of the members separately.

In general, the lithology consists of a sequence of medium- to coarse-grained, cross-bedded, grayish-red to brownish-red sandstones with subordinate interbedded brownish-red shale. The upper 500 feet at Doubling Gap (subquadrangle III-6) is quartzitic. A medium-grained conglomerate is present 70 feet below the top, and flat, ellipsoidal, shale pebbles are common throughout the formation. The lower half of the formation at Doubling Gap is mostly concealed, but contains some quartzite and some friable sandstone. At the base of the Doubling Gap section a coarse, friable, conglomerate is exposed near the contact with the Martinsburg shale. This conglomerate has previously been referred to the Bald Eagle Formation (Willard and Cleaves, 1939, p. 1177), but in this report is included in the base of the Juniata Formation as a conglomeratic member. In the Run Gap section, 600 to 700 feet below the top of the formation, some of the sandstones are characterized by numerous small rusty spots similar to those which Swartz (1955, p. 8) observed in the East Waterford Member and which were attributed to the weathering of crystals or small crystal aggregates of ankeritic carbonate.

No fossils were observed other than tube-like burrows oriented perpendicular to the bedding. The burrows, plus noticeable, lumpy-weathering bedding surfaces are distinctive in the upper portion of the Run Gap Member and serve as a mapping aid in mountainous country.

The best section observed in the quadrangle was the section at Doubling Gap which, although slumped and incomplete in the lower portion, is probably 1,000 feet thick.

The contact of the Juniata Formation and the overlying Tuscarora Formation is fairly sharp, showing minor intertonguing of the red

Juniata and the light-gray Tuscarora. The intertonguing is generally confined to 5 feet of thickness or less. Some small pebble conglomerate is present at the contact but the most striking feature of the upper Juniata is the compact, quartzitic lithology of the Run Gap Member which, except for the red and gray color difference, resembles the Tuscarora Formation.

SILURIAN SYSTEM

TUSCARORA FORMATION

The Tuscarora Formation was named by Darton and Taff (1896, p. 2) after Tuscarora Mountain. The type locality was not specifically mentioned, but could be any of two or three gaps along the mountain where the formation is fairly well exposed. The name has been applied extensively throughout the folded belt of Pennsylvania.

The Tuscarora Formation underlies the prominent ridges of Blue and Bowers mountains in the southern portion of the quadrangle, and Conococheague and Tuscarora mountains in the northern portion of the quadrangle. The thickness varies from approximately 350 feet at Dublin Gap (subquadrangle III-6) to 561 feet at Run Gap (subquadrangle I-3).

The Tuscarora Formation is a white to light-gray, fine- to coarsely grained, quartzitic sandstone. It is medium- to thick-bedded with cross laminations showing a general current direction of northwest to west. In most places the lithology cannot be seen in detail because of the extensive scree which covers the crests and slopes of the ridges. The formation comprises an upper and lower resistant unit which commonly crop out separated by a less resistant unit which is generally covered with talus.

The best section encountered is in Run Gap. The lower portion and the contact with the underlying Juniata Formation is exposed along the road on the west side of the valley. A greater proportion of the formation including the upper unit, is exposed on the east side of the valley. The upper contact of the formation with the Rose Hill Formation is well exposed in a borrow pit at the west end of Sheaffers Valley one mile east along the valley road from the western boundary of the quadrangle. The exposure shows a sharp break between the lower shale member of the Rose Hill Formation and the top of the Tuscarora Formation.

The only fossils observed are the characteristic Arthropycus allegheniensis (Harlan) which are present as knob-like masses of intertwined cylindrical forms which parallel the bedding surfaces. The masses are convex on the undersides of beds and serve as a criterion for determining the tops of beds.

ROSE HILL FORMATION

The Rose Hill Formation was named for exposures on Rose Hill, Cumberland, Maryland by C. K. Swartz (Swartz et al, 1923, p. 27, 28) and has been traced throughout most of the folded belt of Pennsylvania. It makes up the bulk of the Clinton Group of adjacent areas.

The Rose Hill Formation crops out as benches or subsidiary ridges on the flanks of the major ridges underlain by the Tuscarora Formation, and also forms ridges of a lesser magnitude in the western part of the quadrangle. The thickness of the formation as determined from composite measurements is from 850 to 900 feet.

The formation is subdivided into five units in this report: (1) an upper shale member, 150 feet thick, (2) the highly ferruginous ("iron sandstone" of early reports) Centre* Sandstone Member, 75 to 90 feet thick which thins toward the northern part of the quadrangle, (3) a middle shale member 300 to 350 feet thick, (4) the ferruginous Cabin Hill (new name) Sandstone Member, and (5) a lower shale member 250 feet thick.

The upper shale member is seldom exposed and its presence is generally indicated by grayish-orange, yellowish-orange, and yellowish shale float. The member contains 2 to 6 inch interbeds of highly fossiliferous, calcareous, brachiopod coquina. The middle shale is medium-gray and weathers to olive-gray. The lower shale weathers to a mixture of olive-gray, yellowish, and pale-orange debris. Characteristically, the middle and lower shales contain 1 to 6 inch interbeds of siltstone and very fine-grained sandstone.

The Centre and Cabin Hill members are composed mainly of hematitic sandstone. The upper Centre Member forms a thick sequence of medium- to thick-bedded, brownish-gray to grayish-red, fine- to coarse-grained, slightly conglomeratic, quartzitic sandstone with some interbeds of grayish-red siltstone and shale. The lower Cabin Hill Member comprises an upper 4 to 10 foot unit of hematitic sandstone underlain by 30 to 40 feet of interbedded medium- to olive-gray siltstone and shale, and with 3 to 6 inch beds of brownish-gray sandstone. Toward the bottom of the Cabin Hill Member these thin beds become less red and in some places, especially the southern portion of the quadrangle, are medium-gray with some beds exhibiting pinkish and greenish hues. The sandstone members are the ridge formers in the Rose Hill Formation, and the Centre Member in most places underlies the crest of the ridges.

*The name Burnt Ridge Member was used in place of the Centre Member in the 1959 G. S. A. Guidebook, Field Trip #1, and originally on the map accompanying this report, but it has been decided that the Center (sic, correctly spelled Centre) Member, as defined by Swartz and Swartz (1931, p. 620) is the valid and correct name. (Ed.)

*Type Section of the Cabin Hill Member **

The type section of the Cabin Hill Member of the Rose Hill Formation is located 1.5 miles north of Kistler (subquadrangle I-8) on the south side of Pennsylvania Route 850 starting at the borrow pit and extending west approximately 200 feet. The exposure is 3,700 feet south of lat 40°25'N. and 16,600 feet east of long 77°30'W. The overlying middle shale member of the Rose Hill is partially exposed in the borrow pit at the east end of the section. A small amount of the underlying lower shale member is present at the west end of the section.

Rose Hill Formation

Middle Shale Member

Shale and silty shale, medium- to olive-gray.

Cabin Hill Member

Unit	Unit Thickness		Cumulative Thickness	
	Ft.	In.	Ft.	In.
1. Sandstone, brownish-gray, very fine-grained, ferruginous, micaceous, bedding from 3 to 6 inches thinning to 1 inch at base, limonite stained along bedding and cross fractures, contains some fish plates.	4		4	
2. Shale, dusky-yellow to light-olive-gray, some brownish-gray beds, some interbedded light-olive gray siltstone and sandy siltstone.	12	8	16	8
3. Sandstone, brownish-gray, fine-grained, ferruginous, micaceous, bedding from 6 inches to 1 foot.	4	10	21	6
4. Interbedded sandstone, siltstone, and silty shale, brownish-gray, ferruginous, bedding from 1 to 2 inches.	5	5	26	11
5. Shale, light-olive-gray to dusky-yellow, with interbedded siltstone and fine-grained sandstone, middle 1.5 feet ferruginous.	7	8	34	7

*Measured and described by R. R. Conlin and D. M. Hoskins.

Unit	Unit Thickness		Cumulative Thickness	
	Ft.	In.	Ft.	In.
6. Sandstone, brownish-gray, silty, ferruginous, bedding from 2 to 3 inches, with some interbedded light-olive- to brownish-gray shale.	8	4	42	11
			Total	

Lower Shale Member

Shale and silty shale, olive-gray, with some interbedded siltstone.

The Rose Hill Formation is well known in Perry County as the source unit for the low-grade iron ores mined in the 19th century. There are several (as many as five in some areas) thin, non-persistent beds of oolitic hematite occurring at various intervals throughout the Rose Hill Formation. These "ore zones", containing up to 50% iron should not be confused with the thick "iron sandstones" which contain only from 10 to 25% iron. The total quantity of iron in the hematite beds is minor and they are economically unimportant, but the great volume of the lower grade iron sandstones makes them possible future iron ore sources.

The rich ostracod fauna associated with brachiopods, trilobites, pelecypods, gastropods and tentaculoids of the Rose Hill Formation has been studied extensively and subdivided into faunal zones in Pennsylvania and Maryland (Swartz, C. K., et al, 1923; Swartz, F. M., 1934, p. 111-117). In the field it was observed that ostracods of the lower shale member are approximately 1 to 2 mm. in greatest dimension in contrast with some species in the upper shale member which are 3 to 4 mm. in greatest dimension. This provided a rapid means of field identification which was useful in tracing structural complexities. The middle shale unit is not as distinctive in this respect.

The contact of the upper Rose Hill shale with the Keefer sandstone is a sharp, conformable contact. The Keefer probably represents a more near shore environment than do the richly fossiliferous, planar bedded Rose Hill shales. Possibly the hematitic sandstone members of the Rose Hill Formation represent a brackish environment. The fauna in these sandstones is limited, but fragmental remains of fish plates and spines plus meager remains of brachiopods and some ostracods indicate a possible reduced salinity.

MIFFLINTOWN FORMATION

It is here proposed by the author and R. R. Conlin that the

Mifflintown (Lesley, J. P. in Dewees, 1878, p. xxv-xxvi) Formation be redefined to include in ascending order the Keefer, Rochester, and McKenzie formations of previous authors. These units form a single map unit on the Loysville quadrangle and on the adjacent Mifflintown quadrangle. The three units within the formation are locally recognizable depending on thickness and topographic expression, and are retained as members of the formation. Originally, the term Mifflin was suggested by Miller and Conlin (in Arndt et al, 1959, p. 5), but because of pre-occupation it was decided to redefine and clarify Lesley's term.

*Type Section of the Mifflintown Formation **

The type section of the Mifflintown Formation, chosen in cooperation with R. R. Conlin, is a composite section consisting of two exposures near Mifflintown, Pennsylvania, in the Mifflintown 15-minute quadrangle.

The Keefer and Rochester members are very well exposed along the main line of the Pennsylvania Railroad, 0.25 of a mile northwest of the Borough boundary of Mifflin, Pennsylvania. The exposure is 2,900 feet south of lat $40^{\circ}35'N$. and 2,800 feet east of long $77^{\circ}25'W$.

With the exception of the upper 40 feet of the McKenzie member, the complete formation is exposed in a road cut on the east side of U. S. Route 22, 0.3 of a mile north of the Borough boundary of Mifflintown, Pennsylvania. The two lower members are not as well exposed at this outcrop as along the railroad and for this reason the section is presented as a composite one. The highway exposure is 2,000 feet south of lat $40^{\circ}35'N$. and 4,900 feet east of long $77^{\circ}25'W$.

Bloomsburg Formation

Basal 30 feet covered. Grayish-red claystone float present to near small stream. Contact of the Bloomsburg and Mifflintown Formations determined by detailed mapping.

Mifflintown Formation

McKenzie Member

Unit	Unit Thickness		Cumulative Thickness	
	Ft.	In.	Ft.	In.
1. Covered. Light-olive-gray shale float and poor crop in small stream and on bank south of road leading east.	41		41	

*Measured and described by R. R. Conlin and D. M. Hoskins.

Unit	Unit Thickness		Cumulative Thickness	
	Ft.	In.	Ft.	In.
2. Shale, olive-gray with some light-bluish-gray interbeds, weathers dusky-yellow to light-gray, calcareous, poorly fossiliferous, with some interbedded dark-medium-gray limestone, unfossiliferous except in lower portion.	77	4	118	4
3. Interbedded argillaceous limestone and calcareous, silty shale, medium- to medium-dark-gray, bedding ranges from one-eighth to 4 inches. Interbedding has cyclic appearance with shale units less than 6 inches thick. Fossiliferous in upper three-fourths. Three inches of intraformational conglomerate occurs 16 feet above base.	65	7	183	11
4. Limestone, medium-gray, weathering lighter gray. Weathered surface shows rock to be made up of intraformational breccia with platy fragments up to 3 inches long, one-half inch thick, and 3 inches wide showing no preferred orientation. Fragments partially in contact and partially separated by limestone and clayey limestone similar to material of the fragments.	1	5	185	4
5. Limestone, medium-gray, bedding from 1 to 3 inches, with some interbedded calcareous, silty shale.	11		196	4
6. Limestone, medium-dark-gray, weathering medium-gray, granular, crystalline in portions, bedding from 3 inches to 1 foot. Top 1 foot is intraformational breccia.	4		200	4
7. Interbedded, medium-dark-gray limestone and shale, bedding in limestone from one-half to 3 inches, portions fossiliferous.	4	10	205	2
8. Repeat unit 6. Intraformational breccia near top.	2	4	207	6

Unit	Unit Thickness		Cumulative Thickness	
	Ft.	In.	Ft.	In.
9. Repeat unit 7.	5	5	212	11
10. Repeat unit 6. Lenticular intraformational breccia in middle of unit.	3	4	216	3
11. Repeat unit 7. Two inches intraformational breccia 2 feet above base.	6	10	223	1
12. Repeat unit 6. Four inches intraformational breccia at base.	4	6	227	7
			Total	
Rochester Member				
1. Shale, medium-gray, thin-bedded, silty, partially concealed.	2	10	2	10
2. Limestone, medium-gray, with interbeds of medium-gray shale. Beds up to 3 inches thick. Lower limestone beds fossiliferous.	1	11	4	9
3. Shale, medium-gray, thin-bedded, with interbeds of medium-gray, fossiliferous limestone; shale weathers to light-yellowish-brown.	2	6	7	3
4. Shale, medium-gray, thin-bedded, with a few, thin silty beds near middle.	2	8	9	11
5. Shale, medium-gray, thin-bedded, with interbeds of medium-gray, fossiliferous limestone and some light-gray silty interbeds.	4	4	14	4
6. Repeat unit 4. Contains a few limestone nodules.	2	5	16	9
7. Repeat unit 5. Limestone interbeds range from 1 inch to 5 inches in thickness.	5	4	22	1
8. Shale, medium-gray, thin-bedded, with several one-half to 1 inch thick, calcareous, silty beds in lower portion; a few, thin,				

SILURIAN SYSTEM

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Unit	Unit Thickness		Cumulative Thickness	
	Ft.	In.	Ft.	In.
argillaceous limestone beds.	12	11	35	
9. Shale, medium-gray, noncalcareous, with nodular appearance on weathering, sparingly fossiliferous; 7 inches blocky, calcareous, sandstone 6 inches from top.	2	4	37	4
			Total	
Keefer Member				
1. Sandstone, light-gray, fine-grained; plus highly fossiliferous, hematitic limestone. Hematite oolitic in part, occurs in bands parallel to bedding and along vertical fractures, exhibits cross bedding; hematite occurs as ground mass around fossils and as replacement of some fossils.	2	11	2	11
2. Highly weathered, limonitic zone, 2 inches of siltstone at base.	1		3	11
3. Sandstone, quartzitic, medium-gray, fine-grained with some sandy siltstone interbeds, plus intertonguing zones of limestone, in part replaced by hematite; limestone very fossiliferous, sandstone sparingly fossiliferous.	9	5	13	4
4. Sandstone, quartzitic, light-gray to yellowish-gray with some medium-gray mottling, fine-grained, bedding up to 3 feet, middle portion very fossiliferous, limonitic staining throughout.	13		26	4
5. Sandstone, medium- to light-gray, coarse-grained to conglomeratic, pebbles up to one-eighth inch in diameter, beds up to 6 inches thick, cemented with calcite, a few fossils.	3	7	29	11
6. Sandstone, quartzitic, medium-light-gray, fine-grained with some pebbles up to one-eighth inch in diameter. Very fossiliferous, bedding up to 2 feet, lower 1 foot with some				

LOYSVILLE QUADRANGLE

Unit	Unit Thickness		Cumulative Thickness	
	Ft.	In.	Ft.	In.
shale chips up to one-half inch long.	4	3	34	2
			Total	
Total Formation Thickness.....			299	1

Rose Hill Formation

Shale, light-olive- to medium-gray with some sandy and silty interbeds.

In the Loysville quadrangle, the formation occurs along the foot-hills of the Rose Hill Formation ridges and the thickness varies from 150 to 200 feet.

On the Loysville quadrangle, the Keefer Member varies from 30 to 50 feet in thickness. The Rochester Member, though poorly exposed on the quadrangle is considered to be 20 feet thick in the central portion and 30 feet thick in the northern part of the quadrangle. The McKenzie Member varies from 110 to 130 feet thick.

The Keefer Member is a fine- to coarse-grained, medium- to thick-bedded, light- to dark-gray, quartzitic sandstone. It is locally cross laminated and varies from a 50 foot thick continuous sequence of quartzitic sandstone, as on the south side of Burnt Ridge (subquadrangle III-3), to an interbedded sequence of 5 to 10 foot units of quartzitic sandstone and dark-gray, pyritiferous, fossiliferous shale and siltstone. The interbedded sequence is present at the Hidden Valley Boy Scout Camp, 150 feet northeast of Shermans Creek in a small borrow pit north of the camp bridge, and also in a roadcut exposure north of Lower Tuscarora Church (subquadrangle I-1).

The Rochester Member consists of dark- to medium-gray shale with thin- to medium-thick interbeds of crystalline, highly fossiliferous limestone.

The McKenzie Member is dominantly a medium-gray, medium- to thick-bedded, very fine-grained limestone with some interbedded units of shale. Near the base are beds of intraformational breccia consisting of flat limestone fragments.

The most accessible and well exposed composite section is located at Waggoners Dam, west of Loysville, and in a roadside exposure 0.4 miles farther west. This section was described by Swartz and Swartz

(1931, p. 626 - 629), and in their description the Keefer unit is designated the basal member in the Rochester Formation but in later publications the two units are raised to formational rank.

The fauna of the Mifflintown Formation is varied, consisting of a rich ostracod fauna, brachiopods, trilobites, and other marine forms which have been studied and correlated by C. K. Swartz and F. M. Swartz (1931) and F. M. Swartz (1935).

The upper contact of the Mifflintown Formation is gradational. In several localities the McKenzie Member is olive-gray, silty, and sandy at the top and grades transitionally through 10 to 20 feet of section with the brownish- and grayish-red, sandy, silty shales of the overlying Bloomsburg Formation. This transitional relationship corresponds with the findings of C. K. Swartz and F. M. Swartz (1931, p. 656), namely that the Bloomsburg Formation merges eastward with at least the upper half of the McKenzie Member.

BLOOMSBURG FORMATION

The Bloomsburg Formation was named by I. C. White (1883, p. 252) for exposures along Fishing Creek at Bloomsburg, Pennsylvania. White stated that the Bloomsburg "represents the basal member of the Salina Series as defined by New York geologists." Claypole (1885, p. 51) recognized the Bloomsburg of Perry County as a unit analogous to the Bloomsburg red beds of I. C. White, but thinking in terms of the New York section, included the Bloomsburg and overlying Wills Creek Formation in a group numbered Vb after H. D. Rogers' designation and named them the "Onondaga" red and variegated shales. The term "Onondaga" as used by Claypole is not in any way analogous to the present day Devonian Onondaga Formation

On the Loysville quadrangle, the Bloomsburg Formation underlies much of the marginal farmland between the broad fertile valleys and the wooded ridges underlain by the Tuscarora Formation. The thickness of the Bloomsburg Formation is fairly constant at 500 feet in the Loysville quadrangle, but regionally thins toward the northwest.

The Bloomsburg Formation, though commonly referred to as a shale, is very silty and sandy. The color varies from brownish-red in the argillaceous beds to grayish-red in the siltstones and very fine-grained sandstones. The color difference is apparently due to the increased quartz fraction in the sandy beds. The Bridgeport Member (Claypole, 1885, p. 57) in the mid-Bloomsburg is a fairly persistent, though lenticular, unit throughout the southern and central portions of the quadrangle. It is approximately 10 feet thick at the type locality south of Bridgeport (sub-quadrangle IV-6). Lithologically, it is a medium- to thick-bedded, light-

to olive-gray, partly conglomeratic, quartzitic sandstone. The area of maximum development is in Stillhouse Hollow, southwest of Landisburg. Exposures were found in Kennedys Valley, Sheaffers Valley, and as far north as Fort Robinson. In the western and northern portions of the quadrangle, fossiliferous shale and silty shale beds in the mid-Bloomsburg may represent a more marine facies of the Bridgeport Sandstone.

The only fossils reported in the Bloomsburg Formation prior to current investigations have been the brachiopod Lingula and a few ostracods (Claypole, 1885, p. 51). In the Fort Robinson section, 2 or 3 thin beds occur below the Bridgeport Member which contain poorly preserved brachiopods and ostracods. This and similar occurrences in the Mifflintown quadrangle and Sunbury quadrangle have prompted investigations by Hoskins and Conlin (1958) and Hoskins (personal communication) which have revealed a locally abundant fauna of ostracods and some other forms in the Bloomsburg Formation.

The best exposed section of the Bloomsburg Formation in the Loysville quadrangle is along Pennsylvania Route 274 at Fort Robinson (subquadrangle III-3).

The contact of the Bloomsburg Formation with the overlying Wills Creek Formation is fairly sharp within specific sections observed. It is best observed on the north side of the Route 274 near Centre (subquadrangle III-3). The solid red of the upper Bloomsburg contrasts distinctly with the alternating red and nonred of the Wills Creek. There is more sandstone in the upper Bloomsburg than in the lower Wills Creek, thus throughout the quadrangle, the contact is expressed as a topographic break, the Bloomsburg forming a ridge, distinct from the valley underlain by the lower Wills Creek.

WILLS CREEK FORMATION

The Wills Creek Formation was named by Uhler (1905, p. 20-25) for exposures along Wills Creek near Cumberland, Maryland. The formation has been traced or described throughout much of central Pennsylvania but has not been previously mapped on the Loysville quadrangle. Claypole (1885, p. 52, 53) recognized this unit as "variegated shale" and included it in his "Onondaga" formation, but did not map it separately.

The Wills Creek Formation underlies much of the cultivated area in Perry County in the vicinity of Landisburg, Andersonburg, and Ickesburg. The thickness of the formation is 625 feet in the central and northern portions of the quadrangle, and perhaps greater in the extreme southeastern portion. The formation is subdivided into two members, an upper member 170 to 200 feet thick, and a lower member 450 feet thick.

The lithology of the Wills Creek Formation varies laterally within the quadrangle and provides valuable data which show a transition between different environments. The two members are local and unnamed, but aid in understanding the environmental transition. The upper member is mostly nonred in the central portion of the quadrangle, with red only in the upper 15 or 20 feet and with one thin red horizon in the middle of the member. The remainder consists of interbedded medium-gray, calcareous shale, limestone, and olive-gray, somewhat calcareous siltstone. Mud cracks and polygonal columns are common. Traced east toward New Bloomfield and south toward Blue Mountain the amount of red increases in the upper member. Traced north and northwest toward the Mifflintown quadrangle the amount of red decreases.

The red Landisburg (Lesley, 1892, p. 768-772) Tongue at the top of the upper member is composed of interbedded red and grayish-green sandstone and siltstone. The sandstone can be traced north to the Mifflintown quadrangle, but north of Tuscarora Mountain is yellowish- and olive-gray rather than red as it is farther south. Conlin (personal communication) has observed that the upper member is less definitive farther north. Thus north of the Loysville quadrangle the disappearance of the red in the upper member of the Wills Creek causes it to be included in the base of the Tonoloway Formation, thinning the Wills Creek and thickening the Tonoloway.

The lower member of the Wills Creek Formation is a sequence of interbedded grayish-red, olive, and olive-gray siltstone, shale, and very-fine-grained sandstone interbedded with olive- to medium-gray calcareous shale and limestone. Near the middle of the member is one unit of cross-laminated, fossiliferous, sandy limestone. The most noticeable feature is the alternation of red and nonred units of 10 to 30 feet in thickness.

In the southeastern portion of the quadrangle there seems to be a considerably greater proportion of red than the formation contains in the remainder of the quadrangle, especially in the upper member. This is significant in relation to the regional stratigraphic changes proposed by Swartz and Swartz (1931, p. 657) which suggest rapid replacement of the Wills Creek Formation and the overlying Tonoloway Formation by Bloomsburg type lithology as one approaches the Susquehanna Gap north of Harrisburg from the west.

The fauna of the Wills Creek Formation is limited. Ostracods occur especially in the upper member; all those observed are of the genus Leperditia. In the mid portion of the upper member a few small brachiopods and gastropods are present. Similar, small brachiopods and ostracods are present in the cross laminated unit of the lower member. In

general, distinctive faunal elements are lacking. A noteworthy element, however, is the presence of casts and molds of ostracoderm scales and plates which are abundant in the sandstone of the Landisburg Tongue.

The best section observed in the Wills Creek Formation is a composite section. The Landisburg Tongue is partially exposed along the south side of Pennsylvania Route 274 west of Cisna Run (subquadrangle III-2). The remainder of the upper member is exposed in a roadcut south of the intersection at Cisna Run. The lower member is exposed along a farm lane on the north side of Route 274 at the west end of Centre (subquadrangle III-3). The lower 40 feet of section at the base of the upper member does not crop out in either of the sections. This portion of the section is expressed as a persistent valley between the upper and lower member ridges. As nearly as can be determined it represents a calcareous interval, perhaps limestone which is less resistant than the remainder of the formation.

The contact of the Wills Creek Formation with the overlying Tonoloway Formation is fairly abrupt throughout most of the quadrangle. The red, sandy Landisburg Tongue contrasts distinctly with the medium-gray limestone of the overlying Tonoloway, however, the bulk of the limestone and calcareous shale of the upper member is quite similar to the Tonoloway Limestone.

TONOLOWAY FORMATION

The name Tonoloway Limestone was used first by Ulrich (1911, Plate 28) but was formally proposed first by Stoše (Stose and Swartz, 1912, p. 7) after Tonoloway Ridge, Maryland. In Pennsylvania, the lithology is similar, and it is bounded above and below by the same formations as at the type locality.

The Tonoloway Formation, in conjunction with the Wills Creek Formation, underlies the major portion of the cultivated land in the Loysville quadrangle and underlies a broad digitate belt which forms the lower slope and valley adjacent to a ridge formed by lower Devonian sandstones and cherts. Topographically, the formation is expressed as a moderately developed stage of sinkhole topography with solution most strongly affecting transverse joints which form shallow swales and ridges on the lower slope of and normal to the adjacent lower Devonian ridge. In the central part of the quadrangle, the formation is 650 feet thick.

Because of deep weathering and a veneer of float from the adjacent lower Devonian sandstones and chert the Tonoloway Limestone affords few outcrops. Abandoned, small to moderate sized quarries expose the upper portion of the formation which is mostly medium-gray limestone. The weathered partings give the appearance of very thin to thick beds, but

the thick beds are characterized in many places by very thin laminae. The remainder of the formation, by interpretation of float and sparse outcrops, is of similar lithology interbedded with very thin-bedded, argillaceous limestone and calcareous shale. In the central portion of the formation some of the limestone is highly argillaceous and silty. Specimens which show casts of halite crystals are found occasionally in float indicating a high salinity in the original environment. Excessive leaching in the mid-portion of the formation may be due to the presence of evaporites which increase the solubility of the limestone. However, the few halite casts found are the only positive evidence for this possibility. The lower Tonoloway Formation crops out in places and is mostly very thin- to medium-bedded limestone and argillaceous limestone, similar to the upper member of the Wills Creek Formation, but less argillaceous. Mud cracks and polygonal columns are common in the formation. The most notable columns are present near the top of the formation and in a weathered outcrop attain an apparent length of as much as 3 to 6 feet. Whether or not these are true dessication polygonal columns is unanswerable.

In the southeastern portion of the quadrangle, east of Bridgeport, pale-red and mottled-red beds are present along the northern slope of Quaker Hill within the Tonoloway Formation. Dyson (personal communication) has indicated that minor red beds seem to be present fairly high in the Tonoloway Formation in the southwest portion of the New Bloomfield quadrangle which is the next quadrangle east.

The fauna of the Tonoloway is sparse in form, but abundant in the number of individuals. Forms of Leperditia make up the bulk of the population, and occur in sizes from that of a pinhead to individuals which attain a maximum length of one inch. Small brachiopods, gastropods, and small ?Favosites sp. were found sporadically in the upper 100 feet of the formation.

No known section on the Loysville quadrangle illustrates the lithology of the Tonoloway Formation adequately. The thick bedded, laminated, upper 75 to 100 feet (Lewistown Limestone of Claypole, 1885, p. 58) is well exposed in various abandoned limestone and crushed rock quarries especially east of Ickesburg (subquadrangle II-4).

The upper contact of the Tonoloway Formation and the overlying Keyser Formation is a sharp break both faunally and lithologically. The relatively barren, planar bedded, laminated, medium- to thick-bedded upper Tonoloway ceases abruptly and is superposed by the diagnostic lumpy, nodular, fossiliferous beds of the Keyser limestone. The influx of large brachiopods and gastropods as well as many other forms of marine life readily delineates the Keyser Formation from the much less fossiliferous Tonoloway Formation.

KEYSER FORMATION

The Keyser Formation was originally mentioned by Ulrich, (1911, p. 563-591) and later defined by C. K. Swartz (in Schuchert et al, 1913, p. 85) after Keyser, West Virginia. The Keyser Formation was first considered the lowest formation in the Helderberg Group, but was conditionally reassigned by Swartz (in Willard et al, 1939, p. 49) as the highest formation in the Silurian System. Reeside (1917) and F. M. Swartz (in Willard et al, 1939) have described sections of the Keyser Formation of central Pennsylvania at length.

The Keyser Formation is persistent in the Loysville quadrangle and underlies the upper portion of the escarpment slope of the "limestone ridges" throughout the area. Limestone Ridge north of Loysville and Limestone Ridge in subquadrangle I-2 are typical examples. The thickness of the formation is fairly constant at 165 to 175 feet in the central and northern parts of the quadrangle.

The lithology of the Keyser Formation is distinctive. It is mostly thin- to thick-bedded, irregular to planar bedded, medium-gray limestone. In many places there are beds of small 1 to 2 inch nodules near the base. In the mid portion of the formation is a persistent coral zone characterized by larger nodules, commonly 4 to 8 inches in diameter. The upper Keyser is less nodular, with 1 to 3 inch platy beds dominating. The lithologic features which make the Keyser Formation distinct from the Tonoloway are the abundance of fossils, the lack of laminated bedding, and the presence of lumpy, nodular bedding.

The fauna of the Keyser is abundant, both in generic types and individual populations. There is an abundance of brachiopods, corals, crinoid stems and calyx fragments, cystoid rhombs, tentaculoids, ostracods, and some gastropods and trilobites. Extensive studies of the fauna (Reeside, 1917) have shown the presence of faunal zones, some of which can be identified in the quadrangle.

The freshest and most complete exposure known on the Loysville quadrangle crops out in a road cut, a quarter of a mile south of the intersection in the village of Pine Grove (subquadrangle I-8).

The contact of the Keyser Formation with the overlying Helderberg Formation is fairly abrupt. The lithology changes to crystalline limestone with diagnostic fossils in the lower Helderberg. The faunal change is nearly coincident with the occurrence of the lowermost chert nodules which characterize the overlying Helderberg.

The age of the Keyser Formation has been and still is problematic among stratigraphers. Swartz (in Willard et al, 1939, p. 47-49) notes a

transgression of time by the formation from New York to Virginia, but it has generally been assigned to the uppermost Silurian in recent years. Boucot (1957) on the basis of recent comparisons of the Keyser fauna with the fauna of the European section feels that the Silurian-Devonian break may be assigned to the mid-Keyser of central Pennsylvania.

DEVONIAN SYSTEM

HELDERBERG - ORISKANY FORMATIONS UNDIVIDED

The Helderberg and Oriskany units of central Pennsylvania have each been assigned group status (Swartz and Cleaves in Willard et al, 1939, p. 29-130). However, in the Loysville quadrangle, because of thinness of the lithologic units and the general lithologic similarity it was necessary to combine units in mapping. A chert unit overlain by a sandstone unit is the sequence which can be delineated and throughout most of the map area the two are mapped separately. However, north of Tuscarora Mountain, the sandstone unit is thin and is combined with the chert unit on the map. To avoid mapping two groups in one map unit, it is deemed advisable to locally downgrade the Oriskany and Helderberg groups to formation rank and to downgrade the formations within them to member rank. Thus, the terminology used in this report is:

Oriskany Formation

Ridgeley Member

Shriver Member

Helderberg Formation

New Scotland Member

Coeymans Member

The map units south of Tuscarora Mountain are the Helderberg Formation and Shriver Member of the Oriskany Formation undivided and Ridgeley Member of the Oriskany Formation. North of the mountain, the map unit is the Helderberg and Oriskany formations undivided.

The Helderberg and Oriskany formations persistently underlie the crests of the limestone ridges referred to under the Keyser Formation. The thickness of the cherty unit is 100 to 150 feet; the thickest measurement is found in the northern portion of the quadrangle. The Ridgeley Member is 35 feet thick in the eastern mid portion of the quadrangle, and thins west and north to 20 feet at Kistler (subquadrangle I-8) and five to 10 feet north of Tuscarora Mountain. The Coeymans Member, at the base

of the Helderberg Formation is five to 10 feet thick. The overlying New Scotland and Shriver Members of the cherty section each compose approximately half of the remaining 140 feet of the cherty unit.

The cherty unit consists of varied proportions of medium-bedded chert, cherty and non cherty, medium-gray limestone, and fine- to medium-grained sandstone. Shaly, dark-medium-gray limestone and calcareous shale is present in the mid portion of the unit in the northwestern portion of the quadrangle. Extreme leaching of the calcareous fraction of the unit in most places has reduced all outcrops to silty and sandy clay and chert rubble in a clay matrix. This is true even in fairly recent roadcuts where the chert is essentially still in place. The color of the weathered chert appears to grade from dark-gray near the base to yellowish-gray in the mid portion, to whitish-gray in the upper portion of the unit. Claypole (1885, p. 59-60) was the first to note the color contrast of the chert, but to what extent this color sequence persists laterally is unknown. It also is not an infallible observation even within the quadrangle.

The Helderberg Formation can be subdivided into the Coeymans and New Scotland members in ascending order. The Coeymans Member is a medium-gray, coarsely crystalline limestone, usually containing the valves of Gypidula coeymanensis accompanied by large crinoid stems. Thin, dark-gray chert is closely associated with or immediately below the Coeymans Member. The next higher, or New Scotland Member contains bedded chert in the lower portion which grades up into limestone and cherty limestone. It is probably of the order of 50 to 75 feet thick. The New Scotland Member is characterized by the diagnostic brachiopod Eospirifer macropleurus and other forms. The chert commonly weathers to a yellowish- or light-gray. Locally, a sandstone unit is present in the New Scotland Member. It has been named the Falling Springs Sandstone Member (Swartz in Willard et al, 1939, p. 57) after the type locality on the New Bloomfield quadrangle. The sandstone is five to ten feet thick and the lateral extent is unknown although it is fairly persistent in the central sector of the Loysville quadrangle.

At the top of the cherty unit is a zone approximately 50 to 70 feet thick which has been assigned to the Oriskany Formation. Due to a lack of outcrop the Shriver is difficult to distinguish from the New Scotland, but the outcrop belt is commonly divided in the mid portion by a shallow swale underlain by a lithology less resistant than the upper and lower cherty zones. As nearly as can be determined, the swale is underlain by weathered dark-medium-gray shaly limestone and calcareous shale which crops out in the vicinity of Academia (subquadrangle I-1). Whether or not the shaly mid portion of the section is Shriver or New Scotland has not been determined. Acrospirifer murchisoni is common in the Shriver chert and lends the fauna an Oriskany aspect. Commonly the chert nodules show a weathered rind which in thin section shows a silica network from which

carbonate has been leached.

The upper contact of the chert is gradational with the overlying Ridgeley sandstone as seen in a borrow pit 0.3 of a mile south of the intersection at Kistler (subquadrangle I-8).

In the eastern-central portion of the quadrangle, the Ridgeley Member comprises interbedded, conglomeratic, quartz sandstone, medium- to coarse-grained quartz sandstone and fine- to medium-grained quartz conglomerate. The largest pebbles are approximately one inch in greatest diameter. The sand grains are angular and the pebbles subangular to rounded. Toward the west and north the grain size decreases to fine- and medium-grained with very few pebbles.

In the northwestern portion of the quadrangle, the sand unit is only five or ten feet thick and is interbedded with the underlying chert. The thin sand unit is persistent six miles northeast at least to Port Royal where Conlin reports (personal communication) seven feet of Ridgeley overlain by Shriver type chert containing an Oriskany fauna. Seven miles to the southwest at Honey Grove, the Ridgeley is a maximum of two feet thick. Three miles farther southwest at East Waterford (Arndt et al, 1939, p. 26) the Ridgeley is approximately five feet thick and four miles west of East Waterford, at Peru Mills, the sandstone is 50 feet thick (D'Invilliers, 1891, p. 388). At New Bloomfield the Ridgeley is 35 to 40 feet thick and conglomeratic. Thus the Ridgeley sandstone of the Loysville quadrangle represents the northwest thinning edge of a fan-shaped body of sandstone which at its extremities interfingers with the Shriver chert bearing an Oriskany fauna. Eight or nine miles northwest across strike from Peru Mills, the Ridgeley thickens rapidly to more than 200 feet in Mifflin County. Fossils, though abundant, are poorly preserved in the Ridgeley sandstone of the Loysville quadrangle. Acrospirifer murchisoni is the most common brachiopod form while Costispirifer arenosus, the diagnostic Oriskany brachiopod is notably rare and may be missing over considerable areas.

The contact at the top of the Ridgeley Member is very distinctive. The best exposure found is 0.1 of a mile southwest of the intersection at Bixler (subquadrangle III-3). At the top of the Ridgeley are three feet of sandy, bedded, hematitic clay overlain by three feet of blue-gray clay containing dark-gray, oolitic, phosphatic nodules, overlain by dark-gray, oolitic, claystone. The hematite, light-gray clay, and nodules are characteristic of this contact over a large area and suggest conditions of quiescence accompanied by a slow rate of deposition.

The porosity of the Ridgeley sandstone makes it an excellent aquifer, which causes excessive leaching and deep weathering in the overlying Onondaga Formation and the underlying Helderberg Formation.

ONONDAGA FORMATION

The name Onondaga was first applied by James Hall (1839, p. 293-309) to a limestone overlying the Oriskany sandstone in exposures near Onondaga, New York. Willard (Willard et al, 1939, p. 142) raised the term to a group term, but in the Loysville area the member units are not mapped and it is here downgraded locally to the Onondaga Formation.

The Onondaga Formation, together with the Marcellus Formation, underlies a laterally persistent valley which separates the Helderberg-Oriskany ridge from the prominent ridge underlain by mid-Devonian sandstones which crop out along several trends in the eastern portion of the quadrangle. The formation is 65 feet thick at Milltown (subquadrangle IV-3) and thickens northward to 110 feet, east of Ickesburg, increasing to 150 feet or more in the southern portion of the Mifflintown quadrangle (Conlin, personal communication).

The Onondaga Formation is mostly an olive-green weathering, medium-gray limestone and calcareous shale which weathers to a soft, argillaceous claystone. At the base, several feet of thin-bedded, oolitic, dark-gray claystone form a local, distinctive member. Thick beds of limestone typify the upper 10 or 15 feet of the Onondaga Formation. The lithology becomes less and less calcareous toward the base, until, in the lower part of the formation, it is essentially a noncalcareous claystone. In much of central Pennsylvania the Onondaga is subdivided into two formations (Willard et al, 1939, p. 142), the upper or Selinsgrove Limestone and the lower or Needmore Shale. These are not separately mappable on the Loysville quadrangle. The name Newton Hamilton proposed by Swain (1958, p. 2865-2869) is synonymous with Onondaga as used here.

The fauna of the Onondaga Formation is varied and has been studied in local section east of Alinda (subquadrangle IV-3) by E. M. Kindle (1912, p. 30) and on the New Bloomfield quadrangle by Swartz and Swain (1941, p. 390-392). It is distinguishable from the underlying Oriskany fauna, and is characterized by Anoplothea acutiplicata (Goulding) near the base of the Needmore Shale. The thick limestone beds at the top of the Selinsgrove Limestone commonly contains a fauna of diminutive marine forms.

At the contact of the Onondaga Formation and the overlying Marcellus Formation there is a rather sharp break from the limestone lithology of the Onondaga Formation to the black carbonaceous shale of the Marcellus Formation. In several places, the upper three to five feet of the Onondaga and the lower foot of the Marcellus are extremely leached, leaving a porous rock with a silica network and a clay zone. In outcrops where the lithology is fresh, the top 2 or 3 feet of the limestone is dark-gray and generally carbonaceous, showing a partial transition to the

conditions of Marcellus deposition. Five-tenths of a mile east of Bixler (subquadrangle III-3) the contact is exposed, showing a 3 or 4 foot leached contact zone. At the base is a thick bed of medium-gray limestone which grades up into a leached limestone associated with iron and silica rich residual materials. Overlying the leached limestone is a three foot zone of clay minerals and leached argillaceous constituents. Overlying and interbedded with the clay zone are 4 to 6 inches of medium-grained micaceous siltstone composed of 40 to 50% brown illitic mica and altered feldspar grains. The micaceous siltstone occurs at or just below the contact with contorted black shale of the overlying Marcellus Formation. After a detailed analysis of the clay rich beds, Lapham (personal communication) has determined the ascending sequence to comprise a silica-aluminum gel at the base, accompanied by natrolite, gibbsite, and possibly by allophane, overlain by zones dominated by iron hydroxide concretions, illite-montmorillonite, interlayered chlorite and then kaolinite, proceeding toward the top. A vein of barite crystals up to 1-1/2 inches in length transects the entire sequence. The clay sequence from bottom to top appears to represent an alteration sequence in response to changing pH conditions and is presumed to be a K-bentonite originally two to three feet maximum thickness. The sequence is significant in that the Tioga "meta-bentonite", known in many part of Pennsylvania and New York, should occur at this approximate horizon.

HAMILTON GROUP

The Hamilton Group was named by Vanuxem (1840, p. 380) and was later redefined by Willard (1935 a, p. 202) to include the rocks between the top of the Mahantango Formation (Willard, 1935 a, p. 205) and the bottom of the Marcellus Formation. In the Loysville quadrangle the group is defined on the same basis and the top is placed at the top of the Sherman Ridge Formation (new name in this report).

MARCELLUS FORMATION

The term Marcellus was first used by James Hall (1839, p. 295-296) for black shales in the New York section. Claypole (1885) adopted the term Marcellus, and applied it to both the Marcellus of this report and the underlying Onondaga Formation. Willard (1935 a, p. 202) subdivided the Marcellus Formation of Juniata County into four members, in ascending order, the Shamokin black shale, Turkey Ridge sandstone, Mexico sandstone, and Mahanoy black shale. Current work in the Mifflintown and New Bloomfield quadrangles has prompted acceptance of all members proposed by Willard except the Mexico sandstone which has been shown to be the same unit as the Turkey Ridge sandstone (Conlin, personal communication).

The Marcellus Formation underlies the adjacent valleys and lower

slopes of the prominent ridges formed by the sandstones of the Hamilton Group. The black shale of the lower or Shamokin Member increases in thickness from 75 feet at Milltown (subquadrangle IV-3) to 110 feet east of Ickesburg (subquadrangle II-3). In the same area east of Ickesburg, the sandstone of the Turkey Ridge Member averages 145 feet thick and the Mahanoy Member averages 120 feet thick.

The lithology of the Marcellus Formation is threefold. The Shamokin Member is a distinctive, fissile, carbonaceous shale which weathers into thin, platy fragments. The Turkey Ridge Member is a medium- to thick-bedded, fine- to medium-grained sandstone which varies in color from olive-gray to medium- and dark-gray. The Mahanoy Member varies laterally from dark-gray to black, silty shale and very fine-grained sandstone. Willard (1939, p. 173) maintains that the lithology of the Mahanoy and Shamokin members are alike, but the sandy, silty aspect of the upper member is not similar to the carbonaceous, fissile lower member in any of the area studied. The black color of the Mahanoy beds decreases and the average grain size increases slightly toward the southeast, and in the eastern-central portion of the quadrangle the predominate color is olive-gray with very thin interbedded black laminae. In the major syncline north of Tuscarora Mountain much of the Marcellus is dark-medium gray to black shale, and the members are difficult to distinguish from one another, although the lower member retains a distinctive fissility. Traced to the southern portion of the Loysville quadrangle the upper member gradually loses the distinctive black and dark-gray color, grading into the olive-gray siltstone and fine-grained sandstone facies of the lower Montebello Formation. Throughout the area, however, the lower or Shamokin Member persists as a carbonaceous, fissile shale which in places is silty and sandy, especially in the upper portion. Elliptical limestone nodules up to two feet in greatest diameter, and small, platy marcasite nodules occur sporadically in the Shamokin Member. In places, as exposed in roadside borrow pits in the first outcrop belt south of Ickesburg (subquadrangle III-4), the Shamokin shale is interbedded with non-fissile, shaly, carbonaceous limestone, and calcareous claystone. The vertical extent and lateral variation of the calcareous Marcellus is unknown.

Fossils are virtually nonexistent in the Marcellus Formation in the quadrangle. One or two small, unidentified brachiopods and a few Styliolina were found.

Sections which illustrate the relationship to adjacent units are rare. The Shamokin Member is fairly well exposed at Milltown (subquadrangle IV-3) showing the relationship of the member to the overlying Montebello Formation. The three member relationship is best shown by a road bank and gutter exposure along the dirt road south from School #4 in subquadrangle II-2.

The upper contact of the Mahanoy Member with the overlying Montebello Formation, where observed, is a sharp contact. The lowest Montebello is fine- to medium-grained, olive-gray sandstone which resembles the olive-gray phase of the Turkey Ridge Member of the Marcellus Formation. However, the lowermost Montebello is generally fossiliferous, containing brachiopods and other forms.

Willard (1935 a, p. 217) identified the black shale at Susquehanna Gap as the Mahanoy Member of the Marcellus Formation. He stated that the Shamokin and Turkey Ridge members are nonexistent at Susquehanna Gap because of on-lap of successively higher units onto the Harrisburg axis. However, in the Loysville quadrangle the Turkey Ridge and Mahanoy members can be seen to pass by facies change into the lower part of the Montebello Formation while the Shamokin Member persists throughout the quadrangle as the typical Marcellus black shale. The same situation exists to the east, in the New Bloomfield quadrangle (Dyson, personal communication). Thus, tracing of the Marcellus members from west to east supports the thesis that the Shamokin Member of the Marcellus Formation is represented as black shale at Susquehanna Gap and that the Mahanoy and Turkey Ridge members are equivalent to the lower part of the Montebello Formation.

MONTEBELLO FORMATION

The term Montebello was first used by Claypole (1885, p. 67) for exposures at the Montebello Narrows on the New Bloomfield quadrangle. Later Willard (Willard et al, 1939, p. 198) used the term Montebello sandstone facies of the Mahantango Formation for the sandstone facies prominently developed in Perry County.

The Montebello Formation in the Loysville quadrangle underlies a prominent ridge in the eastern and north-central portions of the quadrangle. The average thickness of the formation is 1000 feet. In the Susquehanna Gap section 20 miles to the east, Claypole and later Willard considered the thickness to be 800 feet. The thickness variation is explained later in this section of the report.

The lithology of the Montebello sandstone is distinctive. An approximate composite section subdivides the formation into 5 units as follows:

5. Light-gray sandstone with tube-like burrows and other fossils.
4. Olive and olive-gray fossiliferous siltstone and shale.
3. Light-gray sandstone with some conglomerate and feldspar fragments, highly fossiliferous in some areas.
2. Dark-medium-gray, fossiliferous shale and siltstone.
1. Olive-gray fossiliferous sandstone.

Fossils are abundant throughout the Montebello Formation. North of Tuscarora Mountain the lower Montebello (units 1 and 2) contain, among other forms, a small variety of Tropidoleptus carinatus, Chonetes mucronatus, both abundant, and a few specimens of Spinocyrtia granulosa. A unit tentatively identified as unit 3, south of Ickesburg, contains a prolific number of a large variety of brachiopods. Willard (Willard et al, 1939, p. 139) has correlated the lower Montebello of Perry County with the Skaneateles of New York. This will be discussed further in the section on the proposed Sherman Ridge Formation.

The upper contact of the Montebello Formation is a fairly sharp contact within a limited area. The contact in the Loysville quadrangle is placed at the top of the upper light- to olive-gray quartzitic sandstone. The lower part of the overlying Sherman Ridge Formation contains abundant sandstone interbedded with shale and siltstone, but the sandstone is more argillaceous and ferruginous than the upper Montebello. The contact was chosen at the top of the quartzitic sandstone because of the mappability of the more resistant sandstone and the identifiable characteristics such as the tube-like burrows.

The top of the Montebello sandstone at Susquehanna Gap, as defined by Claypole (1885, p. 314) is marked by a bed of oolitic hematite. Prolonged investigation has shown that a bed of oolitic hematite persists in the New Bloomfield quadrangle (Dyson, personal communication) as well as in the Loysville quadrangle. In some areas it is difficult to find, but is distinctive even in the float of plowed fields. In the gap in Sherman Ridge south of Ickesburg, the oolitic hematite is exposed at the base of a borrow pit east of the road, 280 feet stratigraphically above the top of the Montebello as mapped. If the oolitic hematite proves to be one persistent horizon, then the top of the Montebello at Ickesburg is 280 feet lower in the section than at the gap in Little Mountain north of Harrisburg. Thus, if one considered the oolitic bed as the top of the section in the Loysville quadrangle, it would mean the 800 feet of sandstone at Susquehanna Gap is expanded to approximately 1,280 feet of section south of Ickesburg.

SHERMAN RIDGE FORMATION

The Sherman Ridge Formation is here defined as including all the rocks between the top of the Montebello Formation and the base of the Rush Formation in the Loysville quadrangle. The Sherman Ridge Formation is a tongue of the Mahantango Formation of central Pennsylvania and is not considered to be equivalent to any of the Mahantango subdivisions heretofore described.

Sherman Ridge in subquadrangles II-2, -3, and -5 is the type area designated for the formation. No exposure or exposures exist which

can be established as a type section. The Sherman Ridge Formation crops out in the foothills along the dip slope side of the ridges underlain by the Montebello Formation. The main outcrop belt in the quadrangle is in the major syncline of quadrangle II. The thickness of the formation is 600 feet on the Loysville quadrangle, and at New Bloomfield is 475 feet thick.

The essential features of the Sherman Ridge Formation are expressed in sub-units. The upper unit is dominantly shale and siltstone and lies above the oolitic hematite bed and is equivalent to the upper Hamilton shale of Claypole (1885, p. 66, 68). The lower unit is dominantly sandstone and siltstone and lies below the oolitic hematite bed, but is neither as clean nor as quartzitic as the underlying Montebello sandstone. The upper unit is more fossiliferous than the lower unit, especially in the upper 50 feet.

The fauna has been identified by Willard (Willard et al, 1939, p. 183) Willard and Cleaves (1933, p. 774-779) as a Moscow fauna in the uppermost beds, underlain by a Ludlowville fauna. A persistent zone of belemnites, a fossil common in the Ludlowville fauna, occurs 200 feet below the top of the formation. Other common fossils which occur above the oolitic bed are a large variety of Tropidoleptus carinatus, Mucrospirifer mucronatus, Spincyrta granulosa, Cyrtina hamiltonensis, Phacops rana, and rare individuals of Cornellites flabella, Athyris cora, and Chonetes rugosus ?.

The upper contact of the Sherman Ridge Formation with the overlying Rush Formation is characterized by a lithologic break as well as by the introduction of different faunal elements. Lithologically the medium-gray and olive shale of the uppermost Sherman Ridge is overlain by 3 to 5 feet of grayish-green argillaceous limestone at the base of the Rush Formation. In places, the base of the Rush is characterized by limestone nodules (Tully) 3 to 5 inches in diameter. Where outcrop is poor, the base of the Rush can be approximated by the occurrence of black to dark gray, unfossiliferous, fissile shale (Burket) which overlies the limestone.

SUSQUEHANNA GROUP

The Susquehanna Group (Miller and Conlin, in press) is defined to include all rocks between the top of the Hamilton Group and the top of the red beds of the Catskill Formation. The base of the Susquehanna Group in the Loysville quadrangle would, therefore, be placed at the top of the Sherman Ridge Formation.

RUSH FORMATION

The term Rush was first used as a formation name by Willard (1935 b, p. 1199) for exposures in Rush Township, Northumberland County,

and is defined to include the Tully member at the base and the overlying Burket member. In the Loysville quadrangle, the Burket black to dark-gray shale is difficult to distinguish from the overlying dark- to medium-gray Harrell shale because of sparse outcrop in lowland country.

The thickness of the Rush Formation can only be approximated for this area and may be as thin as 100 feet or as thick as 200 feet. The well exposed section along the Juniata River in the New Bloomfield quadrangle shows a thickness of 210 feet (Dyson, personal communication). The Tully Member is approximately five feet thick and the remainder of the thickness is assigned to the Burket Member.

The Tully Member is a drab-olive, very argillaceous limestone. The Burket Member is a black to dark-gray, fissile shale interbedded with dark-medium-gray shale. The lower part of the Burket Member is black, fissile shale which weathers to a distinctive light-gray and is easily identifiable in plowed fields and road banks. The weathered shale fragments, when broken, reveal a dark, carbonaceous interior. In many places, the upper part of the Burket is dominantly dark- to dark-medium-gray rather than black as is the lower part of the member. Six-tenths of a mile east of Eschol (subquadrangle II-2), a borrow pit on the north side of the road exposes the upper part of the Sherman Ridge Formation and 3 to 5 feet of Tully argillaceous limestone. Seven hundred to 800 feet northeast along the road the Burket crops out in the road banks. Seven hundred feet northeast along the road from the Burket outcrop, a borrow pit on the south side of the road exposes dark-medium-gray calcareous Harrell type shale with a zone of nodules as well as one or two beds of flat pebble limestone conglomerate. This calcareous zone, with occasional limestone nodules, is mapped as the base of the Harrell Member of the Fort Littleton Formation in this report. Similar calcareous beds are present northwest along the road from Taxen School (subquadrangle II-8).

In subquadrangle II-4, 300 yards northeast along the road from the road intersection named Roseburg, a small borrow pit on the north side of the road exposes the Tully "limestone" at the east end of the pit. The Tully here is less calcareous than east of Eschol, and in contrast contains limestone nodules, but the lower part of the Burket Member exposed in the road bank east of the pit is similar to the Eschol sequence.

The upper contact of the Rush Formation with the overlying Harrell Member of the Fort Littleton Formation is transitional, the Harrell Member lithology being somewhat more silty and sandy than the Burket shale. The contact has been placed as mentioned above at the base of noduliferous, calcareous siltstone and claystone beds which weather into elongate, pencil shaped fragments.

The Tully Member contains an abundant fauna similar in some

aspects to the underlying Sherman Ridge Formation. The black shale of the Burket Member apparently represents a toxic environment, because fossils are rare and consist mainly of a few small pelecypods and pteropods.

The base of the Upper Devonian has been placed in the past alternately at the base and top of the Rush Formation. Willard (Willard et al, 1939, p. 201) includes the Rush Formation in the Upper Devonian. However, Cooper (Cooper et al, 1942, p. 1733) on the basis of faunal evidence places equivalents of the Rush Formation in the Middle Devonian, a classification which is followed in this report.

FORT LITTLETON FORMATION

The Fort Littleton Formation is defined by Willard (1935 b, p.1199) as consisting of, in ascending order, the Harrell, Brallier, Losh Run, Trimmers Rock, and Parkhead members, which are closely knit and intergrade vertically and laterally. The section in the Loysville quadrangle is assigned to the Trimmers Rock and Harrell members.

The Fort Littleton Formation in the Loysville quadrangle is distinctive topographically and comprises a belt of discontinuous ridges dissected by many transverse valleys and less prominent longitudinal valleys. The thickness of the formation, based on the average of three calculations, is 2,550 feet, of which only the lower 100 feet or so is assigned to the Harrell Member.

The lithology of the formation is not known in detail because of a lack of outcrop, but interpretation of float and knowledge of sections nearby provide generalities. The unit as a whole is characterized by a monotony of lithology which, from the base to the top, changes gradually from medium- to dark-medium-gray shale to interbedded medium- and olive-gray, thin- to thick-bedded, flaggy siltstone and shale to medium- and olive-gray, fine-grained, medium- to thick-bedded sandstone and siltstone. The basal 100 feet or so is typical Harrell type shale and siltstone. The remainder of the formation weathers to shades of drab-olive and olive-gray. Minor grayish-red beds interbedded with medium-gray beds are included in the upper part of the formation.

The fossils of the Fort Littleton Formation are abundant in some beds. Some of these persist along strike for known distances of 1 1/2 miles and probably farther. One zone in the upper mid-portion of the formation abounds with Productella lachrymosa and many fragments of crinoid columnals.

The upper contact of the formation as mapped, is drawn at the base of the first distinctive red bed 160 feet below the base of the first distinctive gray sandstone (Kings Mill sandstone, Claypole, 1885, p. 73)

above the base of the red beds. In southeastern Perry County, at least 500 feet of beds below the Kings Mill sandstone are characterized by frequent red beds as measured by Claypole (1885, p. 287) near Kings Mill and Linton Hill on the New Bloomfield quadrangle. However, this part of the section seems to be much less red in the northeastern part of the Loysville quadrangle.

CATSKILL - FORT LITTLETON TRANSITION BEDS

Claypole (1885, p. 75-76) recognized the necessity for "Catskill passage beds" as he termed them, stating that they should be called neither Catskill nor "Chemung". With the exception of the traceable red beds of the upper part of the Fort Littleton Formation, the Catskill-Fort Littleton transition beds include in one unit the major portion of the beds which are transitional between the Upper Devonian marine beds and the continental Catskill red beds. The unit as yet is unnamed.

The transition unit is mostly confined to subquadrangles II-3 and -6 and is represented by an outcrop belt of discontinuous, parallel ridges. The unit is approximately 1,400 feet thick.

The lithology of the transition beds is variable, comprising grayish-red to some brownish-red shale, siltstone, and sandstone interbedded with light-gray, medium- to coarse-grained, partly conglomeratic and cross-laminated sandstone. The red of the transition unit is dominantly a grayish-red as opposed to the more brownish-red of much of the overlying Catskill Formation. Five ridge-making sandstones whose thickness vary from 5 to 15 feet are known locally in the transition beds of the Loysville quadrangle. Their lateral extent is unknown except for the lowest or Kings Mill Member. They are as follows, with the intervening rocks interpreted from float:

- 5 Grayish-red sandstone containing crinoid columnals and brachiopods. 250 feet of grayish-red shale, siltstone and sandstone.
- 4 Olive gray, coarse-grained sandstone. Contains tube-like burrows in one outcrop. 185 feet of grayish-red shale, siltstone and sandstone.
- 3 Light-gray, medium- to coarse-grained, cross-laminated sandstone. 360 feet of grayish-red shale, siltstone, and sandstone. Contains Cyrtospirifer sp. and Platyrachella mesastrialis in the lower part.
- 2 Medium-gray, medium-grained sandstone containing green shale fragments. 360 feet of grayish-red shale, siltstone, and sandstone.
- 1 Kings Mill light- to olive-gray sandstone Member. Contains pelecypods and brachiopods. 160 feet of grayish-red shale, siltstone, and sandstone. Contains Platyrachella mesastrialis and possibly ?Cyrtospirifer sp.

with pelecypods.

The fauna of the transition unit is fairly abundant in some beds. The red beds below the Kings Mill Member yield marine fossils, mostly Platyrachella mesastrialis. Other forms are pelecypods and Cyrtospirifer angusticardialis ?.

The upper contact of the transition unit for the Loysville area has been placed tentatively at the base of the lowest major red unit of the Catskill Formation.

CATSKILL FORMATION

The Catskill Formation occupies only a small portion of the Loysville quadrangle near Walnut Grove (subquadrangle II-3 and -6). It is composed of grayish-red to brownish-red shale, siltstone and sandstone with a few nonred interbeds. The lower contact is established at the lowest major red bed unit; the upper contact is not found on the Loysville quadrangle. Whether or not the Catskill Formation is unfossiliferous is unknown at this time. Although the Catskill red beds are generally conceded to be barren, they should not be presumed entirely destitute of fossils. Regional data (Miller and Conlin, in press) indicate the Catskill Formation as defined here to be approximately 3, 500 feet thick.

STRUCTURE

GENERAL STATEMENT

The Loysville Quadrangle is located at the southeastern edge of the Folded Appalachians and includes a small part of the Great Valley. The major structural mode of the Ridge and Valley Section is well illustrated within the quadrangle, although the magnitude of faulting is not as great as in some areas within the section. The western edge of the quadrangle, south of Conococheague Mountain, is a series of major folds of subequal magnitude superposed on a synclinorium 13 miles wide (section E-E', Plate 2). This synclinorium plunges gently to the eastern portion of the quadrangle where four major folds are present (section C-C', Plate 2). The synclinorium in the center and the major syncline at the southeastern end of section C-C' plunge northeastward for more than 60 miles to the Pottsville area in the Southern Anthracite Field, where they are referred to as "northern and southern fishtails" of the Minersville Synclinorium. The major structure separating the two synclinoria is named the New Bloomfield Anticlinorium. The Tuscarora Mountain Anticline and the major syncline at the northwest end of section D-D' (Plate 2) resolve northeastward into the Broad Mountain Anticlinorium of the anthracite belt.

FOLDS

The folds of the Loysville quadrangle (Figure 6) are of a hybrid nature, combining the aspects of both parallel and similar folding. Competent units such as the Tuscarora Formation are folded parallel, while the least competent units such as the Wills Creek Formation show similar fold characteristics. (Plate 2) The result is a disharmonic relationship between different lithologies. The initial reaction to the map pattern (Plate 1) is that disharmonic folding is obvious, but the apparent intensity of the disharmony is excessive owing to misleading outcrop widths exposed on shallow plunging dip slopes.

The axial planes of the folds within the Loysville quadrangle dip steeply. The popular concept that all Appalachian structures are overturned toward the northwest is not applicable. In the southern portion of the quadrangle, many of the axial planes dip steeply northwest. Presumably, if folding had continued until the major folds were oversteepened toward the northwest, then the axial planes of the minor folds would be similarly affected.

The plunge of the structures is locally variable, but can be generalized. The major syncline of Green Valley (subquadrangle IV-6 and -8) plunges 20° and 22° NE. Northwest, across strike, the plunge decreases in magnitude to 5° or less along the "northern fishtail" synclinorium.

The folds of the Loysville quadrangle exhibit various shapes in cross section; some apparently representing different degrees in intensity of folding. Four stages of folding are illustrated which show the progression from an open, symmetrical anticline to a faulted anticline (Figure 3). The disharmonic folds present can result either from shearing of incompetent beds from competent beds (Figure 4), or by the crowding of incompetent beds by competent beds (Figure 5). Three of the 4 stages are illustrated along the "northern fishtail" synclinorium which crosses quadrangles I and II. In cross section A-A' (Plate 2) the synclinorium is an open symmetric type as in stage 1 (Figure 3). Toward the southwest, the central portion of the synclinorium rises more rapidly than the flanks, and in cross sectional shape changes from stage 1 to stage 2 (Figure 3). Southwestward through section F-F' (Plate 2) the synclinorium becomes more and more crenulated. At least one fault is known in this synclinorium in the eastern part of the East Waterford 15-minute quadrangle, and other structural complexities are probable. Also, the folds in the Bloomsburg-Tonoloway sequence of subquadrangles III-1 and -2 become more and more complex as they are traced southwestward onto the East Waterford quadrangle. These features are readily apparent in the map pattern (Plate 1).

Sheaffer Valley in the southwest corner of quadrangle III illustrates a complex, faulted fold. Toward the northeast, the fault displacement

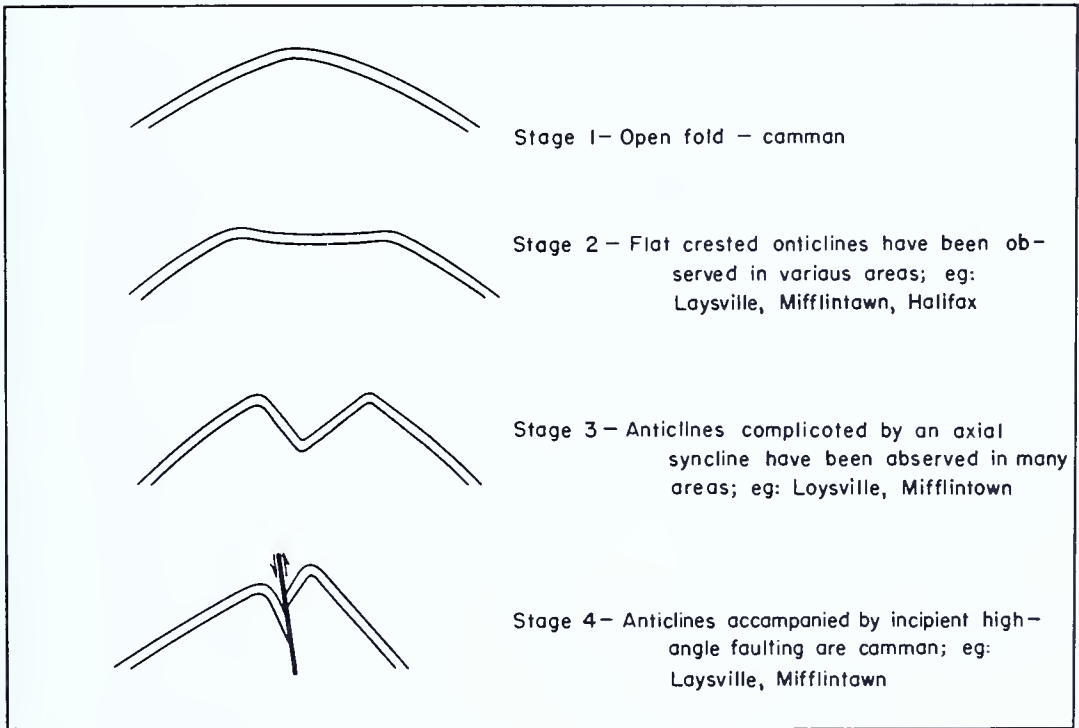


Figure 3. Cross sections of four types of folds observed in central Pennsylvania, which represent stages in the development of some folds.

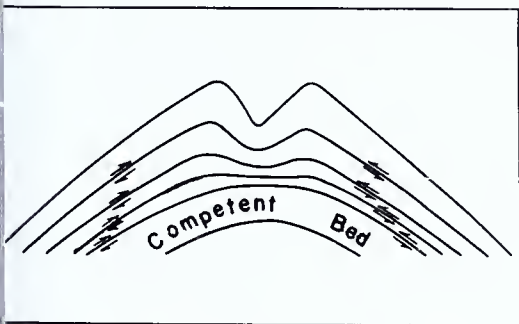


Figure 4. Cross section of disharmonic fold, developed by thrusting of incompetent beds.

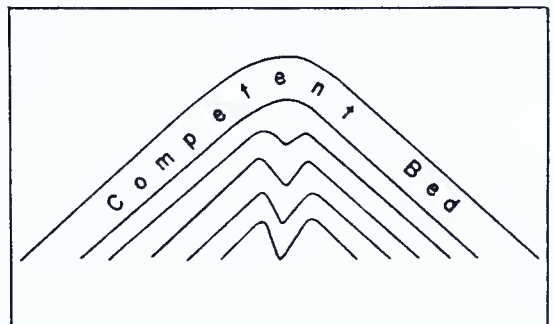


Figure 5. Cross section of disharmonic fold, developed by structural crowding of incompetent bed in core of fold.

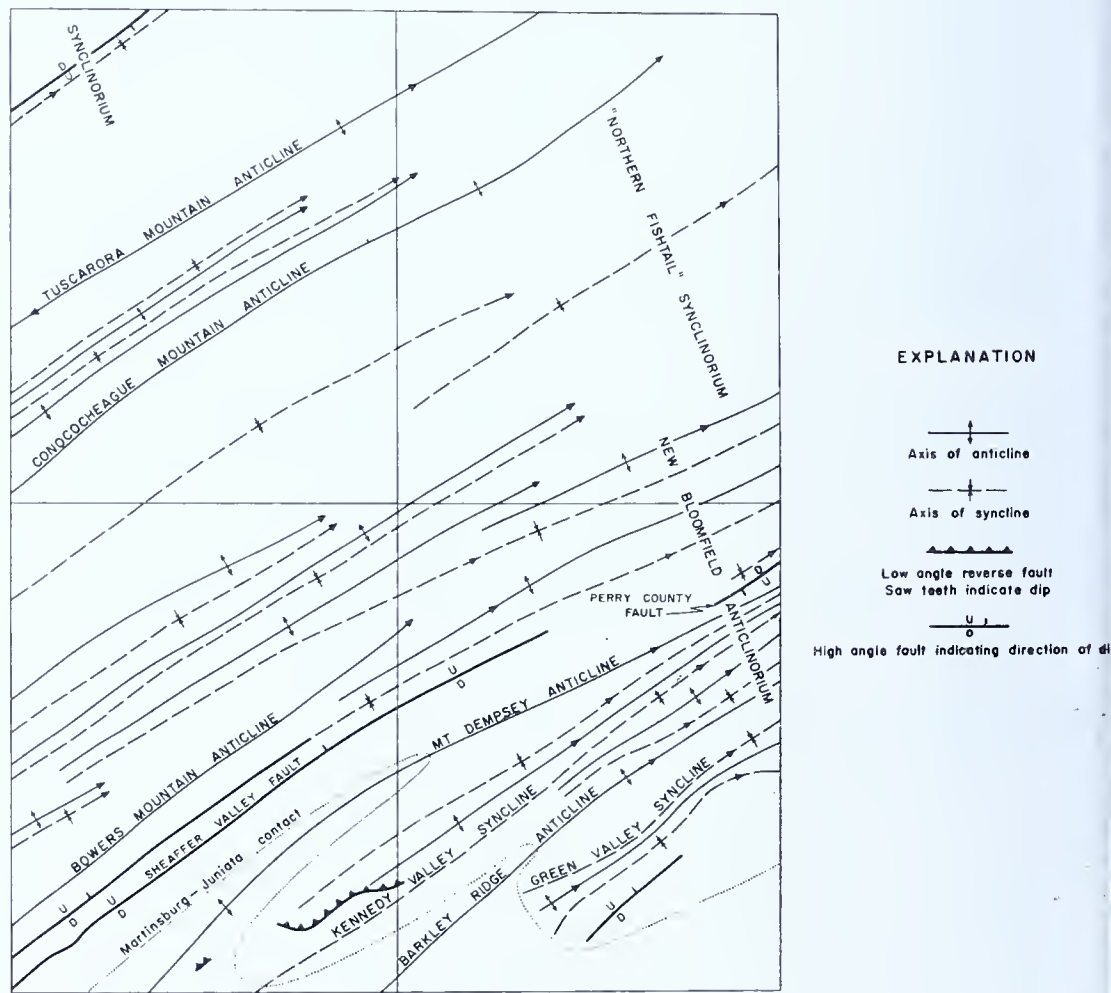


Figure 6. Major structures of the Loysville quadrangle.

decreases and the structure resolves into a double crested anticline in subquadrangles IV-2 and -3.

The syncline in Green Valley (subquadrangles IV-6 and -8) is fairly flat bottomed with a gentle subsidiary fold along the axis in the Tuscarora Formation, but along strike toward the northeast, this fold is sharper and has a greater vertical displacement in the Helderberg and Oriskany Formations. To what extent the fold may be subdued at the top of the Montebello Formation is unknown.

The Mount Dempsey Anticline (subquadrangle IV-5) resolves toward the northeast into a series of crenulations in the Wills Creek Formation and the westernmost known evidence of the Perry County Fault.

Secondary folds on the flanks of major anticlines develop commonly in the Rose Hill and Mifflintown formations and are to some extent developed by bedding plane slip which permits differential movement relative to the underlying Tuscarora Formation. One example is the fold in the Rose Hill Formation in subquadrangles IV-5 and -6 on the north flank of the Barkley Ridge Anticline. Traced southwest this fold is not reflected in the Tuscarora Formation except by a small fault.

The Conococheague Mountain Anticline which is prominent near the north end of section E-E' (Plate 2) plunges toward the northeast, and resolves into a series of smaller crenulations in the higher Silurian and Devonian formations. In section A-A' the north limb is subdued to the extent that the trend makes a step-like form on the south limb of the Tuscarora Mountain anticline.

In many portions of the cross sections, the Middle and Upper Silurian formations are highly crenulated. The overlying, massive Montebello Formation and the underlying, massive Tuscarora Formation respond structurally in a less intricate fashion. In a general way this relationship is the most noticeable manifestation of structural disharmony in the stratigraphic section.

The area of subquadrangles II-9 and IV-3 is underlain by a complex series of folds. These structures are related in that they resolve eastward into the New Bloomfield Anticlinorium.

FAULTS

The largest faults mapped within the quadrangle seem to affect the more competent formations, while the faults of lesser throw, accompanied by pronounced crenulation, occur in the less competent formations. With few exceptions, the known faults in the Loysville quadrangle are high angle reverse faults. The major exception is at west end of Kennedy

Valley (subquadrangles III-8 and -9) where a thrust dips 30° to 35° NW. Another exception is a small southeast dipping normal fault in the northern part of subquadrangle IV-3. It is significant that the four largest faults in the quadrangle, located in the southern area along the crenulations in Blue Mountain, all dip northwest. The average dip of the high angle faults is 70° NW. It is equally significant that the axial planes of the major folds in the southern part of the quadrangle dip steeply northwest.

The Perry County Fault along the south side of Milligan Ridge (subquadrangle IV-3) is a high angle reverse fault which dips steeply south east (Claypole, 1885, p. 81-88; Dyson, personal communication). The faults in the major syncline of subquadrangle I-2 are similar, with an average dip of 70° SE. Thus, the most significant faults in the quadrangle are high angle reverse faults and fall into two general dip categories, i.e. 70° SE. and 70° NW.

The Perry County Fault in (subquadrangle IV-6) shows a maximum stratigraphic displacement of 3,500 feet or more in the New Bloomfield quadrangle to the east (Dyson, personal communication). The two faults at the west end of Sheaffer Valley have maximum stratigraphic displacements in the Loysville quadrangle of approximately 400 feet and 1,100 feet, or a combined displacement of 1,500 feet. Thus, along the trend of the Sheaffer Valley faults and the Perry County Fault, the displacement progresses from west to east from a steep northwest dipping fault upthrown 1,500 feet stratigraphically on the north side to a steep southeast dipping fault upthrown 3,500 feet stratigraphically on the south side. The overall movement is thus a scissors-like movement.

The opposing fault movements are essentially nonexistent in the area of Alinda and Landisburg in subquadrangles IV-2 and -3. However, structural distortion is extreme in this area in the sequence of the Bloomburg through Tonoloway Formations. These formations show a high degree of crenulation. Related but obscure fault movement is also present, along the Centre sandstone trend on the south side of Mount Dempsey where the trend crosses Shermans Creek (subquadrangle IV-5), and in the Bloomburg Formation section exposed in Stillhouse Hollow on the north side of Mount Dempsey.

Many writers think of the Appalachians in terms of oversteepening toward the northwest and overthrusting from southeast to northwest. The general picture of the southern Loysville quadrangle is one of oversteepening toward the southeast and underthrusting from southeast to northwest.

Small scale structures express many of the basic principles represented on a large scale on a quadrangle map. An instructive example is shown in Figure 7, which illustrates a faulted fold exposed in a small

bandoned quarry east of the road, 0.2 of a mile north of bench mark 583, southwest of Round Top, in subquadrangle IV-6. Both bedding plane and cross-cutting faults are illustrated.

STRUCTURAL UNITS

The area underlain by the Martinsburg Formation on the Loysville quadrangle is insufficient in size and the Ordovician structure too complex to warrant any conclusive statements. The general strike of Martinsburg structural trends roughly parallels structural trends in the younger rocks, and the contact with younger rocks was not noted to be unconformable. However, this generality is based on sparse and inconclusive data.

Chevron folds and folds that approach being isoclinal are present in the Martinsburg Formation. Cleavage and joints are related to local structures and there is a notable absence of regional axial plane cleavage.

In the Silurian and Devonian units disharmonic relationships exist between formations of different lithologies. Notably, very complex, small scale structures are evident in the Marcellus Formation at many outcrops. A stream segment along Tuscarora Creek at the north edge of subquadrangle I-2 is added to the edge of the map because it shows well the relationship between the three members of the Marcellus Formation, and also a section illustrates the very crenulated response of the lower member of

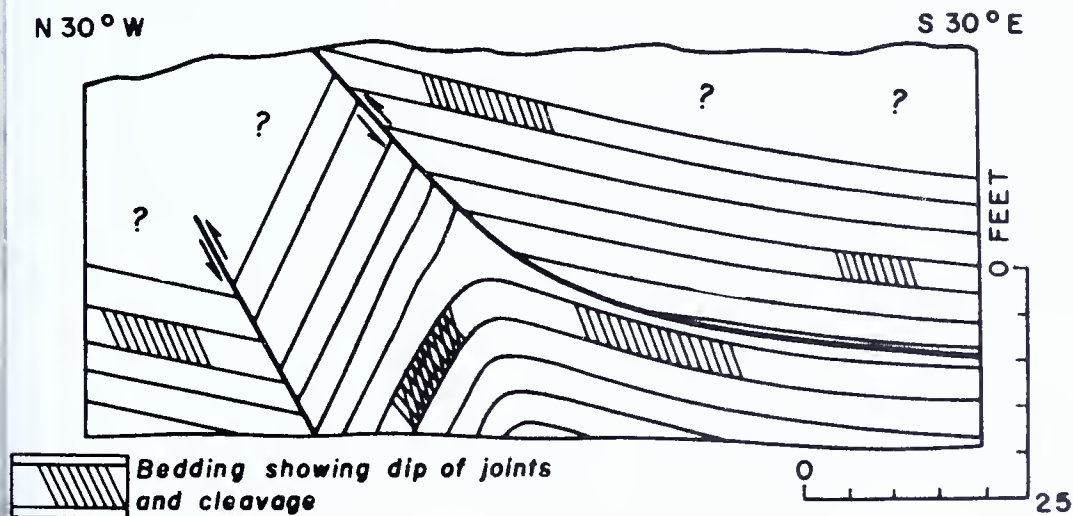


Figure 7. Sketch section of a fold illustrating related faults, joints and cleavage in the Tonoloway Limestone.

the Marcellus to deformation. Similar outcrops can be seen in borrow pits, in which the Shamokin Member is characterized by chevron folds, isoclinal folds, and small faults. Much of the structure is intraformational and implies significant differential movement between the Marcellus and adjacent formations. The Marcellus-Onondaga contact has been observed in only three or four localities, but in each case it shows dragfolds with an amplitude and height of several feet accompanied by cross cutting and bedding plane faults. Displacements involved are unknown, but the Marcellus-Onondaga contact is, to some degree, a plane of structural decollement.

Another incompetent unit is the Wills Creek Formation. On the flanks of folds, the structure present in the lower member of the Wills Creek is usually more complex than in the adjacent, more sandy, thicker bedded Bloomsburg Formation. The characteristic of the Wills Creek which probably contributes most to its incompetency is lithologic heterogeneity. More homogeneous shale units such as those of the Rose Hill Formation respond differentially, relative to competent units such as the Tuscarora Formation, but not to so extreme a degree as the heterogeneous Wills Creek Formation.

Very little is known about the structural response of heterogeneous units such as the Rochester-McKenzie interbedded limestone and shale, 1 one exposure in subquadrangle IV-1 (Figure 8) shows intense small scale faulting and crenulation in a stream bank exposure along the axis of the small anticline on the north side of Bowers Mountain.

Competent units such as the Tuscarora Formation are not extensively affected by intraformational crenulation as are the less competent units, but seem to respond preferentially by faulting. The faults of the southern part of the quadrangle in Green, Kennedy, and Sheaffer Valleys illustrate this relationship, and in each case the fault displacement decreases along strike; the movement apparently becoming absorbed by crenulations and small faults in the Middle and Upper Silurian formations.

DISTORTION

Data in regard to distortion and flow of rocks are difficult to determine. The structural plunge of the area is very gentle and plunge sections are lengthy. This factor combined with limited outcrop and local plunge variation make it nearly impossible to measure accurate thicknesses on axial trends of folds. On a small scale, beds of quartzitic sandstone are known to thicken as much as 25% in the crests of small chevron folds. Incompetent formations in longitudinal cross sections, where the plunge is known, are thicker along fold axes than the known true thickness. However, in the majority of cases the increased thickness is a function of crenulation of incompetent units rather than flowage in an intergranular sense. Thus

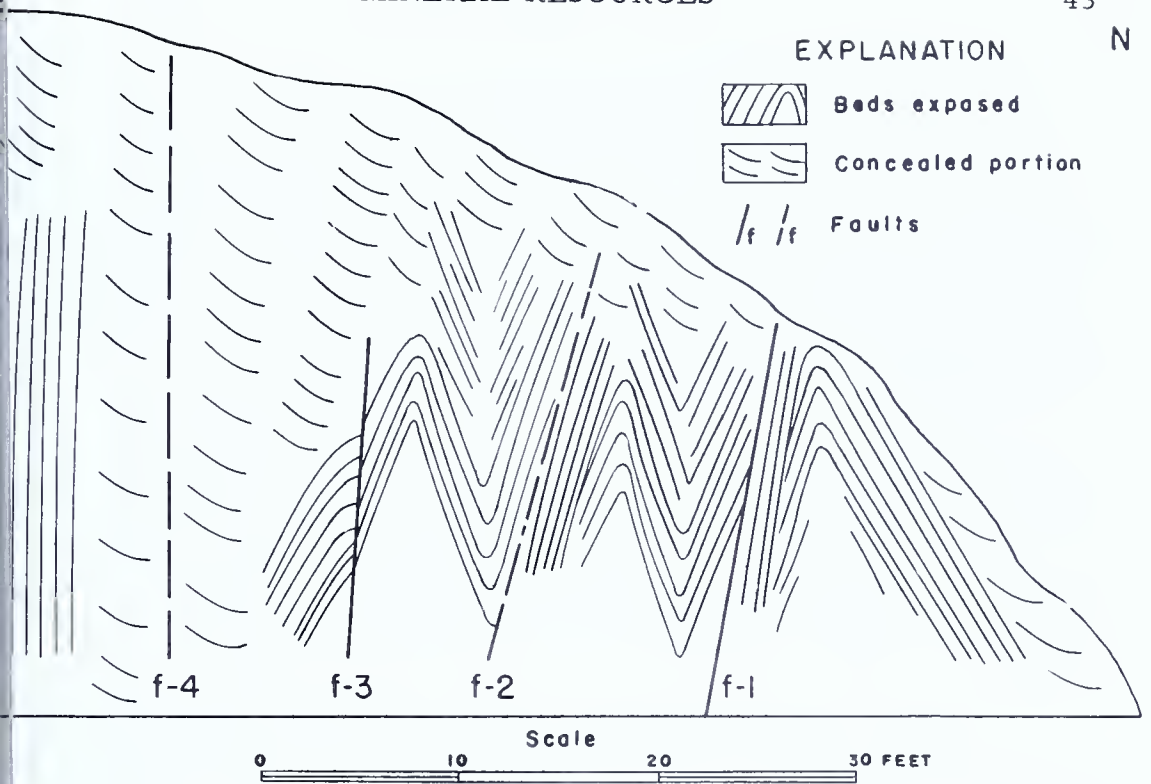


Figure 8. Diagram of stream section showing folded beds of McKenzie limestone and shale.

thickening along axes is a reality, but is largely a result of disharmonic denudation mostly accomplished by bedding plane faults and small thrusts which cross-cut the bedding.

MINERAL RESOURCES

The mineral resources of the Loysville quadrangle are exploited on a small scale and are restricted mainly to local use. Some of the non-metallic minerals and low grade iron ore could be produced in larger quantities if new or better market possibilities develop.

The chert of the Helderberg and Oriskany formation, because of its extreme durability, is used extensively on township roads.

The fine-grained, resistant sandstones of the Fort Littleton Formation provide one of the best sources for future development of crushed rock in the quadrangle. These sandstones are being extensively quarried at Newport, 7 1/2 miles east of the quadrangle boundary.

The Ridgeley sandstone, usually exposed in the chert pits, is friable, and after sifting is used locally for sand. The friable nature of the Ridgeley makes it amenable to beneficiation by washing, but the

thinness of the unit discourages commercial development.

The limestone of the Keyser Formation and the upper 100 to 150 feet of the Tonoloway Formation is the rock which has been quarried most commonly in the past. Many small abandoned quarries are present throughout the quadrangle. During the mid 19th Century, when iron furnaces were active in the area, a considerable amount of limestone was used for flux. Until recently the limestone was used for crushed stone for road beds and agricultural lime, but currently there are no commercial crushed limestone operations within the area.

The quartzite of the Tuscarora Formation is used extensively throughout the state as raw material in silica refractory brick. A silica brick works is located at Van Dyke Station along the northern slope of Tuscarora Mountain just north of the edge of the Loysville quadrangle. Further investigation along the outcrop of the Tuscarora Formation in the Loysville quadrangle might point up areas for future development of silica brick.

Minor amounts of iron were mined and produced throughout this area during the mid 19th Century. The sedimentary ore was mined from small deposits in the Rose Hill Formation, the Keefer Member of the Mifflintown Formation, the Onondaga Formation, and the Marcellus Formation.

One possible future source for iron ore in the Loysville quadrangle is the iron sandstone of the Rose Hill Formation. Analyses of iron sandstone samples collected from the area around Centre show an average iron oxide content of 15%. The iron sandstone attains a thickness of 90 feet in some localities and maintains a reasonable thickness throughout the quadrangle. If a method of beneficiation for such low grade iron ore is ever perfected millions of tons of potential iron could be exploited in the Loysville quadrangle.

Minor amounts of copper carbonate and some sulphide occurs sporadically in the Wills Creek Formation. In subquadrangle I-6, 0.8 of a mile N. 15° E., across country, from the road intersection at Saville, a small, caved-in drift is present, which was dug in the east bank of Panther Creek approximately at the contact of the Wills Creek and Bloomburg formations. Rubble at the drift entrance revealed the bright green of secondary malachite coatings on joint and cleavage surfaces, and one small half inch piece of dark gray chalcocite. The amount of copper found proved insufficient to support the prospect financially.

Minor fluorite occurs in calcite veins in the Upper Silurian limestones. It is occasionally found in the limestone quarries.

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